Vertical Profile of Ultrafine Particles around Urban Office Buildings

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Keywords: particle number concentration, PM2.5 concentration, particle size range

1 Introduction

Motor vehicles emissions are a major source that impacts upon urban environmental air quality, particularly in terms of fine and ultrafine particles. Epidemiological studies have consistently showed the relationship between fine and ultrafine particles and human health effects. Given that outdoor ultrafine particles in the building envelope can penetrate indoors into the building, it is important to understand the vertical profile of particle concentrations surrounding them, in order to locate the optimal location of air intakes to mitigate penetration of outdoor particles indoors. Most of the research to date has investigated the change of particle mass (PM) concentration within the building envelope, however few studies have measured particle number (PN) concentration (Hitchins et al., 2002). Kumar et al. (2009) assessed PN concentrations in various size ranges at street and rooftop levels, however comprehensive information on vertical profiles of PN and PM concentrations are still lacking. In order to fill these gaps in knowledge, we conducted continuous and simultaneous measurements on different levels of different office buildings close to busy roads, in order to: (1) quantify vertical profiles of PN and $PM_{2.5}$ concentrations around the building envelope; (2) compare the correlation efficient between ratios of PN and $PM_{2.5}$ concentrations at different levels; and (3) assess the variation in PN concentrations for different size ranges at the street and rooftop levels of these office buildings.

2 Materials/Methods

Three office buildings close to busy roads in the city of Brisbane were selected and named Building A, B and C. Building A was 20 m high and 10 m from the Northern Busway. Building B was was 25 m high and located close to the Southeast Freeway, while Building C was 80 m high and was located in the heart of the CBD.

Two sets of instruments were used to measure PN and $PM_{2.5}$ concentrations. Total PN concentrations were measured by two TSI condensation particle counters 3781 (CPC 3781), while PN concentrations in different size ranges (from 0.008 to 0.452 μm) were measured by two TSI scanning mobility particle sizers (SMPS 3934) and $PM_{2.5}$ concentrations were measured by two TSI DustTrak Aerosol Monitor Model 8520 (DustTrak). One set of instruments measured continuously at the highest level (rooftop level), being the reference site for each building. The other set conducted simultaneous measurements at different lower levels around the building. Measurements were performed over two to three weeks at each building.

3 Results and Discussions

Vertical profiles of PN and $PM_{2.5}$ concentrations for each building were constructed using the normalised concentrations at each height, along with the relevant concentrations at the reference site. An example for Building A is shown in Figure 1.

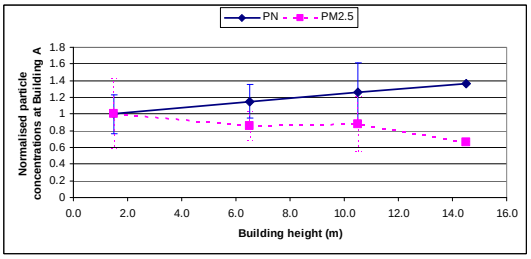

Figure 1. Overall vertical profiles of PN and PM2.5 concentrations at Building A

In general, PN concentrations decreased linearly with height at Building B and C, and inversely at Building A. $PM_{2.5}$ concentrations at all three buildings decreased with height, however their trends were not linear.

The relationship between ratios of PN and $PM_{2.5}$ concentrations varied between different heights and different buildings, and there appeared to be little correlation. In addition, the correlation coefficients were highly dependent on wind speed and wind direction. The results showed that the correlation efficient was higher during low wind conditions compared to high wind conditions, as well as on the leeward side compared to the windward side of the building. This can be explained by the fact that PN and $PM_{2.5}$ concentrations were strongly influenced by particles in different size ranges, while their proportions depended on emission sources and dispersion conditions such as wind direction and speed.

PN concentrations in size range N≤300 accounted for most of the PN concentrations (99.8%). Interestingly, the peak PN concentrations for N30-100 and N<30 mostly appeared during rush hours and in the early afternoon. This was expected in both cases due to: (1) the higher number of vehicles during the rush hours, which has the potential to produce more aitken mode particles; and (2) the higher solar radiation intensity in the early afternoon, which is a vital factor that favors the production of nuclei particles.

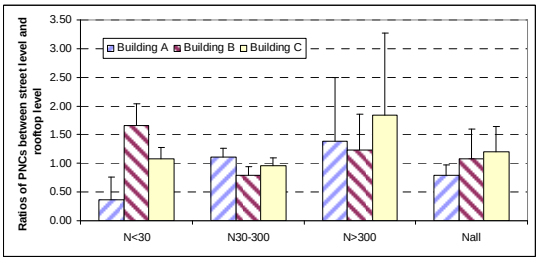

Figure 2: Ratios of PN concentrations in different size ranges at street and rooftop levels.

Ratios of PN concentration in different size ranges between the street and rooftop level of the 3 buildings varied considerably (Figure 2). Total PN concentrations at street level were higher than at rooftop level at Building B and C and whilst these results supported previous findings, their values were relatively lower. On the contrary, PN concentrations at the street level were lower than on the rooftop for Building A. This could be due to the fact that the Northern Busway is above ground level and therefore the bus emissions may have had a stronger influence on rooftop rather than street level concentrations for this building.

The production of new nucleation mode particles was stronger at street level compared to the rooftop level at Building B and C. Although this finding was not supported by previous research, this is feasible since the concentrations of pre-existing particles at street level were lower than at the rooftop level. At the same time, their surface area concentrations at street level were smaller than at the rooftop level. Additionally, the concentration of condensable gases at street level might be higher than at the rooftop level due to their direct emission from vehicles. Hence, at the same solar radiation intensity, the production of nuclei particles at street level should be higher than at rooftop level. In the case of Building A, both concentrations of pre-existing particles and their surface areas at rooftop level were lower than at street level, and the concentration of condensable gases at rooftop level was possibly higher than street level, due to its location closer to the busway. It could explain the stronger formation of new nucleation mode particles at rooftop level than at street level in this case.

4 Conclusions

Vertical profiles of PN and $PM_{2.5}$ concentrations were localised and difficult to standardise for all buildings. The relationship between PN and $PM_{2.5}$ concentrations were relatively weak for all levels and buildings, and mainly depended on wind conditions. This indicates that it is not always appropriate to use $PM_{2.5}$ concentrations to infer PN concentrations and vice versa. In addition, the production of new nucleation mode particles strongly depended solar radiation intensity and vehicle emission source. Therefore, future studies would benefit from monitoring vehicle density and local wind conditions.

References

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